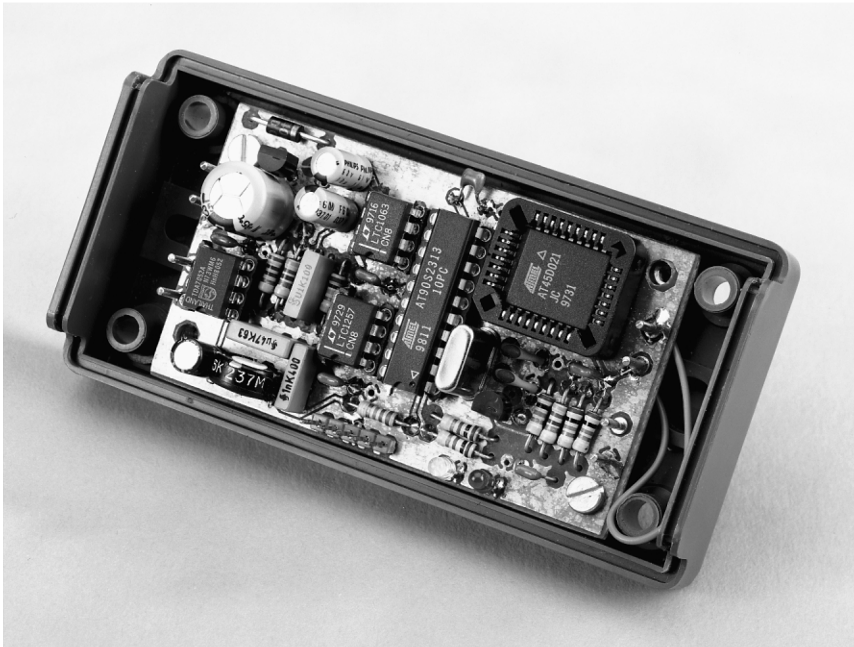
wave file player

a music box that you can program with your PC

Specifications

Controller:	Atmel AT90S2313
Memory:	2 Mbit flash ROM
D/A converter:	12-bit
Filter:	5th-order switched-capacitor
Serial interface:	RS232
Serial format:	57k6, 8N1 *
Sampling frequencies:	6, 8, 11.025 & 22.05 kHz
Playback:	monophonic
Word size:	8 or 16 bits
Playing time:	8 to 43 seconds
Amplifier:	1 watt bridge

* see text



The wave file player is yet another circuit that offers the prospect of several hours of enjoyable tinkering. The PC and the soldering iron work as partners on this project. You have to admit that this is an Elektor project in its best form. The result is a compact circuit that, on command, plays back a sound file that has been previously downloaded via the PC. The wave player can be used as a programmable doorbell, but it can also be used for model railroading or to amuse your children. Depending on the desired sampling frequency and resolution, it can store up to 43 seconds' worth of sound.

Design by H. Bonekamp

Using modern electronic components, it is possible to pack a lot of functions onto a relatively small circuit board. The circuit is also based on existing standards. In practice, this means that the controller works with 'wav' (wave) files. These are familiar to every PC user. Another important factor is that the configuration of the player is automatically derived from data in the sound files, so that the best possible sound quality is always guaranteed.

BASIC ASSUMPTIONS

A number of considerations played a role in the development of the wave file player. We wanted it to be compact, utilize industry standards and be flexible in use.

The interface with the PC allows all the 'tunes' that the player has to reproduce to be generated conveniently and 'made to measure'. Depending on the capabilities of the PC used, sound fragments can be taken from a CD (but watch out for copyright restrictions) or sampled via a sound card. You can use a sound editing program for this (such as the shareware program Cool Edit). Also, thanks to the 'universal' approach used in the design, a Windows environment is not essential. The only thing that you need is a program that can generate and edit wav files. The resulting file must be transferred to the player as a data file, via an RS232 interface. Standard terminal programs can be used for this, as long as they support RAW ASCII. In addition, there is a specially-prepared downloader program available for Windows users.

A CLOSER LOOK AT THE HARDWARE

The block diagram of the hardware design is shown in **Figure 1**. The heart of the circuit is an AT90S2313 IC, which can be connected to a PC via an RS232 interface. On the analogue side we find a D/A converter, a configurable low-pass filter and an adjustable output amplifier. The data are stored in a flash memory. All that's left is the power supply: from a 9 V input, it provides the circuit with 8.4 V and 5 V working voltages. The user interface consists of one switch ('play') and two LEDs ('recording' and 'playing').

Thanks to the power of the controller used here, the entire hardware design needs only five integrated circuits. **Figure 2** shows the full schematic diagram. The serial interface consists of no more than a single transistor and three resistors. The hardware around the CPU can be quickly described. The oscillator components are X1, C1 and C2. The 'play' switch is debounced in software, and resistor R4 protects the IC against electrostatic discharges. Capacitor C3 suppresses any coupled-in high-frequency signals. LEDs D1 and D2 are connected to one of the controller's I/O ports via series resistors. The 2-Mbit flash memory, IC2, is organized as 1024 pages each holding 264 bytes. Since it takes 64 clock cycles to read out one page, it is not possible to simply transfer data directly from the flash memory to the D/A converter. A 64-byte circular buffer in RAM is used to deal with this problem. Data are read from the circular buffer while a page address is being sent to the flash memory. In addition, the data are organized so that the least possible amount of time is lost in reading the data.

The D/A converter is connected to the CPU via three signal lines (CLK, DIN and LOAD). Its output signal (V_{out}) is capacitively coupled to the input of the low-pass filter (IC4). The LTC1063 chip used here is a switched-capacitor device, which filters the analogue signal under control of the CPU. A circuit trick is used to set the input level to the filter to 2.5 V. The necessary supplementary voltage is provided by R8 and R9. Resistor R7 provides a relatively high-

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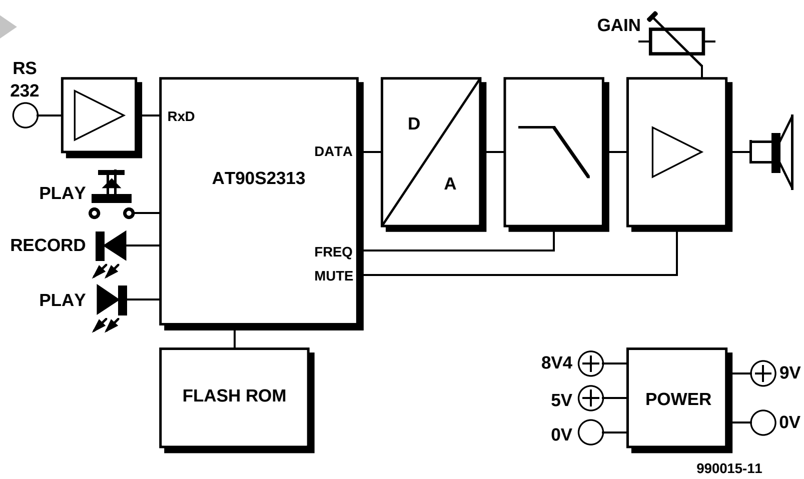

Figure 1. Block diagram of the wave file player.

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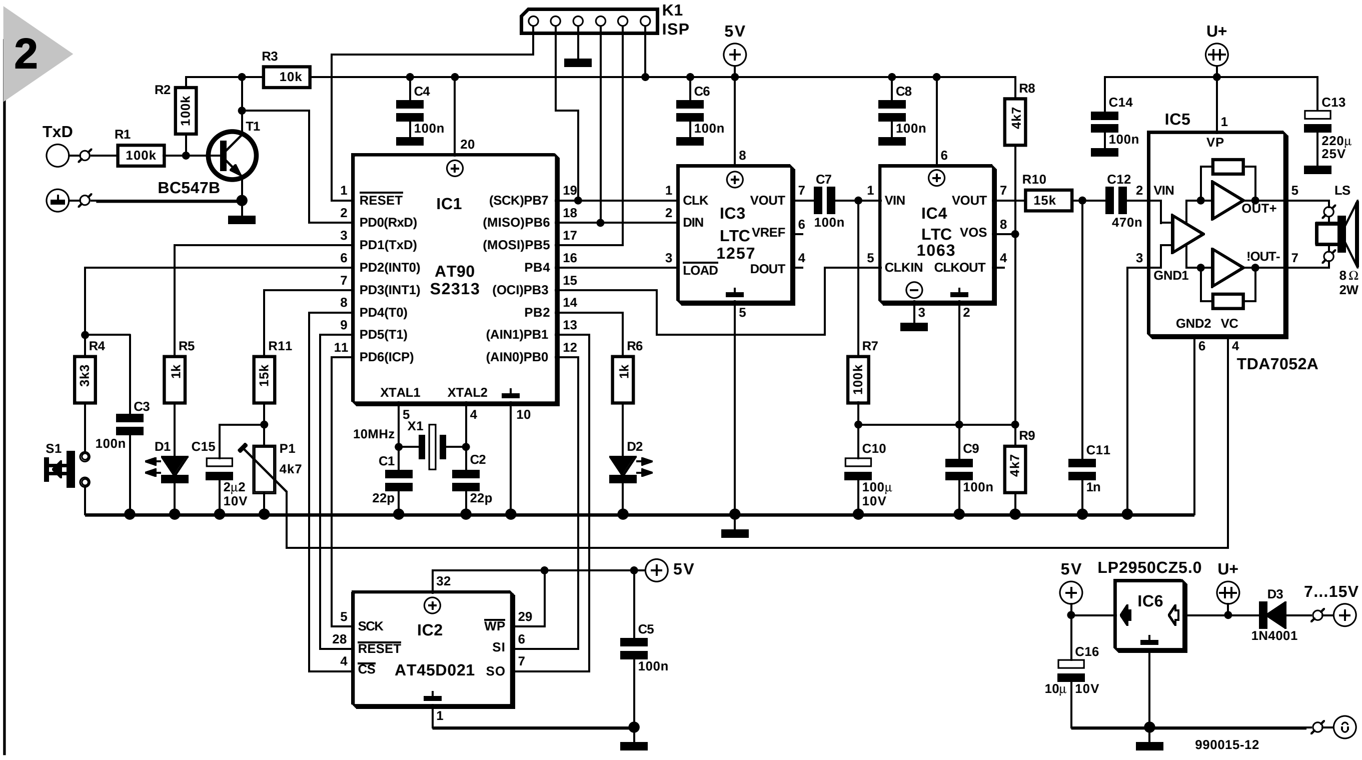

Figure 2. From theory to practice: the complete circuit requires only five integrated circuits.

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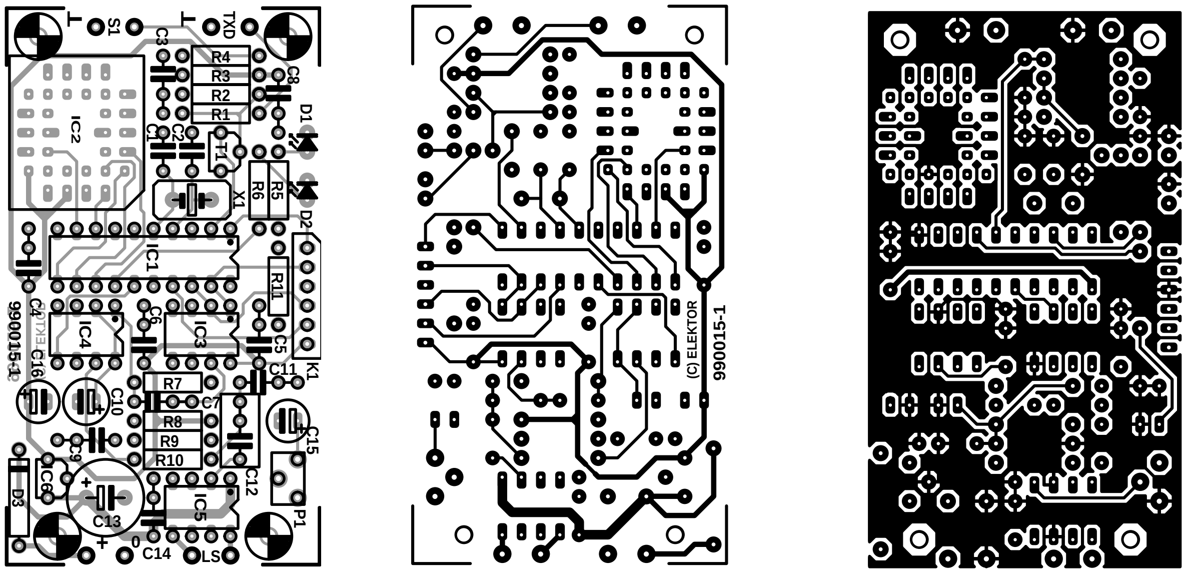

Figure 3. The copper-track layout and component overlay show the compactness of the player. It can easily be fitted into a small enclosure.

impedance path for this voltage to the input of IC4. The filter characteristics can be adjusted by varying the frequency of its clock signal.

The final part of the circuit is the output amplifier IC5. The TDA7052A IC is wired as a bridge amplifier and provides an output power of 1 watt. The volume level can be adjusted via P1. The PD3 output of the processor controls the mute function. The output amplifier is muted after the wave file has finished playing.

Readers who have carefully studied the schematic may well wonder about the function of K1. The answer is that this connector allows the processor to be programmed directly in the circuit. This is a handy option for anyone who wants to modify the microcontroller program to suit his own wishes. The source code of the program, which was developed in the Elektor labs, is readily available from our Readers Services (order number **996006-1**).

Construction should not present any problems. A compact printed circuit board, whose copper track layout and component overlay are shown in **Figure 3**, forms the basis. If you use sockets for the ICs, almost nothing can go wrong. For this reason we can quickly shift our attention to the software, which is the key to the whole show.

Working with Cool Edit

Wave files to be played back by this circuit must first be made to fit, and for this you will need a sound editor for the PC. One possibility is the Windows program Cool Edit, which is preferable to various other programs since it provides good facilities for resampling sound files. This is an important task, which in large measure determines the quality of the sound.

A shareware version of Cool Edit can be found at the website http://www.syntrillium.com. This program has several functions that are particularly well suited to our objectives, including altering the sampling frequency, selecting a particular passage and optimizing the amplitude. In addition, it is easy to make a mono file from a stereo file. This is essential for the wave player, since it makes the file smaller. Finally, the resolution can be selected to be 8 bits (256 levels maximum) or 16 bits.

As can be seen from **Table 1**, the playing time is strongly dependent on the sampling frequency. A high sampling frequency is recommended for music (up to 22 kHz with this circuit), but a lower frequency can be used for speech. By and large, a sampling rate of 8 kHz yields a signal whose sound quality is equal to that of a good telephone connection.

The difference between 8-bit and 16-bit resolution can be seen in the signal-to-noise ratio. The lower the resolution, the larger the steps. With 8 bits, only 256 signal levels are possible. A larger step size results in a greater difference between the actual value and the desired amplitude, which increases the noise and distortion levels. For the best quality, 16-bit resolution should be used. Note also that the player circuit reduces this to 12 bits, since the D/A converter has its own limitations. With these 12 bits we achieve an optimum

COMPONENTS LIST

Resistors:
R1,R2,R7 = 100kO
R3 = 10kO
R4 = 3kO3
R5,R6 = 1kO
R8,R9 = 4kO7
R10,R11 = 15kO
P1 = 4kO7, preset V

Capacitors:
C1,C2 = 22 pF, ceramic
C3…C6,C8,C9,C14 = 100nF, ceramic
C7 = 100nF, MKT
C10 = 100µF 16V, radial
C11 = 1nF, MKT
C12 = 470nF, MKT
C13 = 220µF 25V, radial
C15 = 2µF2 10V, radial
C16 = 10µF 10V, radial

Semiconductors:
D1 = LED, high eff. red
D2 = LED, high eff. green
D3 = 1N4001
T1 = BC547B
IC1 = AT90S2313 10PC (order code 996505-1)
IC2 = AT45D021JC
IC3 = LTC1257 CN8
IC4 = LTC1063 CN8
IC5 = TDA7052A
IC6 = LP2950CZ5.0

Miscellaneous:
32-way PLCC socket for IC2
S1 = pushbutton 1 make contact
LS = 8Ω 2W
K1 = 6-pin SIL pinheader
X1 = quartz crystal, 10 MHz
Case: Bopla type E410
PCB, order code 990015-1
Programmed controller: order code 996505-1
3.5”-floppy disk with Windows-software and source code file of controller program: order code 996006-1.

compromise between the signal-to-noise ratio and the memory capacity. The best possible sound quality can be achieved by using the sound-editing program to adjust the amplitude of the signal so that the full dynamic range is utilized.

Since the wave file player simply cuts off the sound at the end of the available playing time, it is also necessary to modify the sound file so that it starts and ends softly. A bit of experimenting will quickly teach you how everything works.

Once the file is ready, it must be transferred to the wave file player via the serial port. A terminal program can be used for this, as long as it supports the RAW ASCII option. This is the only way to be sure that the data will not be corrupted on its way to the player. For Windows users, we have developed a utility program that drastically simplifies file downloading. This program ensures that the complete wave file is quickly and reliably transferred to the player's memory. Proper configuration of Cool Edit is important, since the controller software checks the structure of the wave file. When the file is received, it is checked to see that:

- it is a wav file,
- the sampling frequency is equal to one of the predefined values;
- the signal is monophonic;
- PCM coding is used and
- the word size is 8 or 16 bits.

If all these conditions are satisfied, then the file can be properly read in. If an error is detected, the red LED is immediately lit.

There is in practice a problem when Windows 3.1 is used. With this software the maximum speed of the serial interface is considerably less than 57.6 kbps, which is used here. It is thus necessary to drop back to a lower speed. If switch S1 is held depressed while the power is switched on, a serial data rate of 9600 baud is selected. All other settings remain unaltered.

The red LED (D1) flashes while data are being downloaded. As soon as the flash ROM is full, it stays on continuously. If no more data are sent to the controller for an interval of 500 ms, the LED is extinguished.

The green LED (D2) is lit when power is applied to the circuit. It flashes while a stored wave file is being played back (in response to pressing S1).

If the player is used as a doorbell, a mains adapter can be used to supply it with power. The doorbell switch then functions as S1. You can welcome your guests on special occasions (such as Christmas or a birthday) by loading an appropriate tune in the ROM. You could also consider programming the sound of barking dogs for your vacation time. This should confuse would-be thieves who try to see if anyone is at home by ringing the doorbell!

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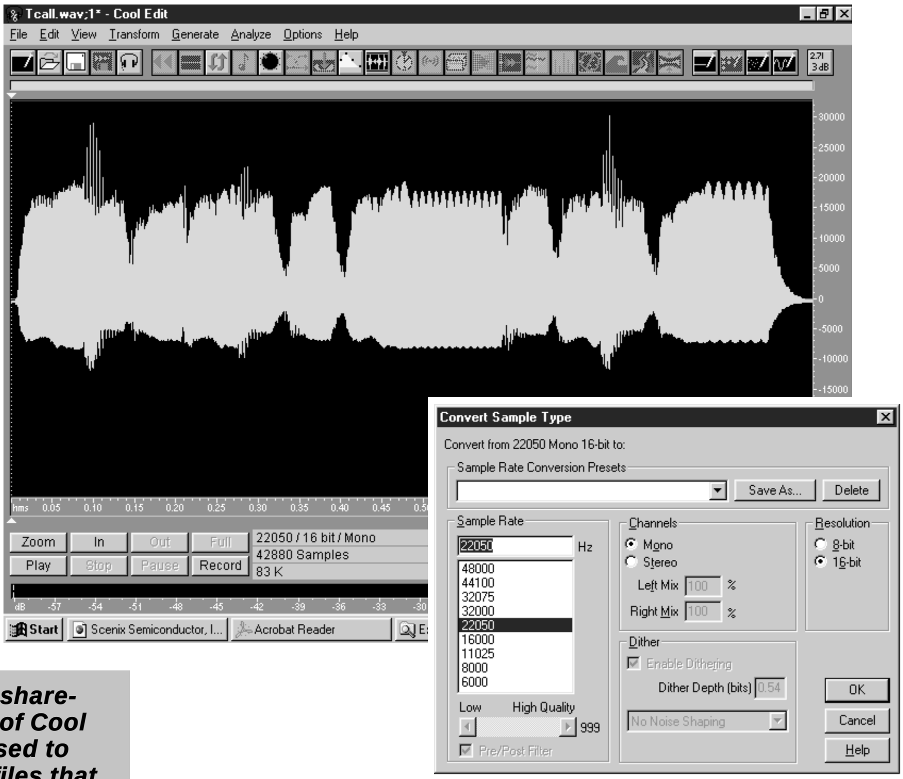

22050 / 16 bit / Mono
42880 Samples
83 K

Convert from 22050 Mono 16-bit to:

Sample Rate: 22050 Hz

Channels: ● Mono ○ Stereo

Resolution: ○ 8-bit ● 16-bit

Figure 4. The shareware version of Cool Edit can be used to make sound files that are suitable for the wave file player.

Table 1. Files, formats and playing times.

Sampling rate	*word size*	*file size*	*playing time*
22.05 kHz	*8*	*256 k*	*11.92 s*
	16/12	*341 k*	*7.94 s*
11.025 kHz	*8*	*256 k*	*23.83 s*
	16/12	*341 k*	*15.89 s*
8 kHz	*8*	*256 k*	*32.77 s*
	16/12	*341 k*	*21.85 s*
6 kHz	*8*	*256 k*	*43.69 s*
	16/12	*341 k*	*29.13 s*